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Double dividends of additional water consumption charges in South Africa

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Abstract

South Africa is a water-scarce country with an average rainfall of 500 mm per year. It is estimated that national water demand will exceed supply by 2025. Increasing the water supply would be environmentally, financially or politically unfeasible. Impoverished communities, especially those in rural areas, require access to water for drinking, cooking and other basic purposes (such as agriculture). Only approximately 24 per cent of rural people have access to water on site. Unemployment in the rural areas of South Africa is estimated at about 34 per cent. This study seeks to explore ways of reducing poverty in South Africa while implementing policies that address water scarcity problems.

The South African Government is exploring ways to address water scarcity problems by introducing a water resource management charge. This will be based on the quantity of water used, and applied to sectors such as irrigated agriculture, mining and forestry. This is expected to achieve both a more efficient allocation and lower use of water, as well as helping to alleviate poverty. This paper reports on the validity of these options, providing more information for the policy-making process. This study applies a computable general-equilibrium model to analyse the double dividend of water consumption charges in South Africa. The first dividend is environmental: more water will be available as a result of an additional water charge; the second dividend is developmental: revenue generated from these charges will be recycled back into poverty alleviation programmes.

PREM Working Paper: 05/01

Keywords: Water scarcity, water charges, double dividend, poverty alleviation, computable general equilibrium model

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Poverty Reduction and Environmental Management (PREM)

PREM aims to deepen and broaden the exposure of economic researchers and policy advisors in developing countries to the theory and methods of natural resource management and environmental economics. It is envisaged that this will encourage effective policy change in developing countries with the joint goals of poverty reduction and sustainable environmental management.

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1. Introduction

This paper[1] analyses a proposal by the South African Government to reduce water consumption by introducing a water resource management charge[2]. The Water Resource Management Charges are implemented to recover the cost of water resource management in each water management area (WMA) in South Africa. It differs from Pigouvian tax, which is a tax on an external cost, such as pollution, designed to use market forces to achieve an efficient allocation of resources. Pigouvian tax attempts to reach optimal welfare; charge is a mark-up cost and has little relation to reaching optimal welfare. The costs of these additional water charges to the South African economy are estimated with a particular emphasis on poverty reduction. The benefits of recycling the water charges revenue into schemes to raise the income of the poor are also evaluated[3].

The literature on the use and availability of water, socio-economic indicators and water policies in South Africa is reviewed in Section 2. Section 3 focuses on the concept of a double dividend and its application to environmental taxation. The model and data used in this paper, including the simulation results, are presented in Section 4 and discussed in Section 5. Section 6 concludes the paper.

2. Water scarcity and poverty in South Africa

South Africa is classified as a semi-arid country. Precipitation has fluctuated over the years (see Figure 1) with an average of 500 m^3 per annum, well below the world average of about 860 mm per year (DWAF 2002). The total flow of all the rivers in the country amounts to approximately 49,200 million m^3 per year. The National Water Resource Strategy estimates total water requirements for the year 2000 at 13,280 million m^3, excluding environmental requirements. In addition, South Africa is poorly endowed with groundwater because most of the country lies on hard rock formations that do not contain any major groundwater aquifers (DWAF 2002).

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1. Paper presented at 2nd International Conference on Environmental Concerns: Innovative Technologies and Management Options, October 12-15, Xiamen, China.
2. This is not pigouvian tax, but a proposal by the Government to reduce water consumption, see Pigou (1920).
3. The recycling of revenue options are designed to alleviate poverty and not to address inequality.

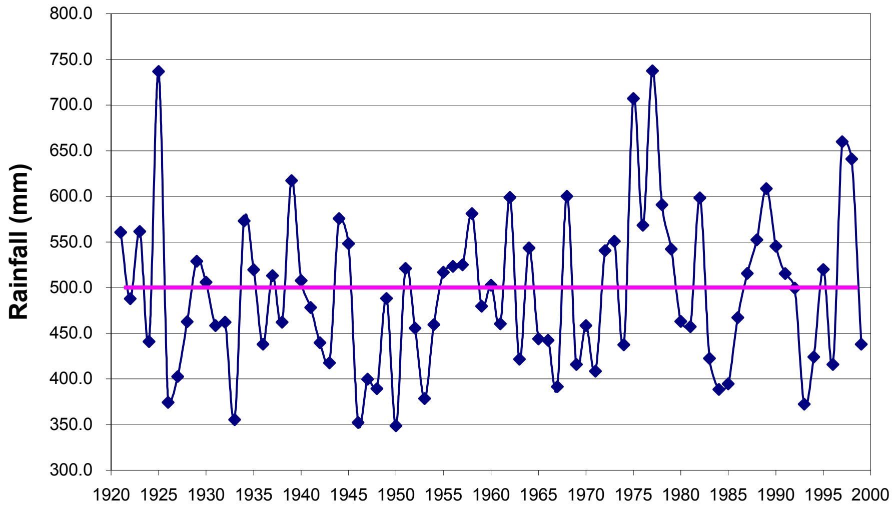

Figure 1 Precipitation in South Africa (1922-1999).

Source: CSIR (2001).

Figure 2 describes water requirements by sector in South Africa. The agricultural sector is the largest consumer of water, at 59 per cent. It is primarily large-scale farmers that use 95 per cent of irrigation water; small-scale farmers use the remainder (Schreiner and van Koppen 2002). Afforestation requires 4 per cent of the total water requirements and rural and urban populations require 4 per cent and 25 per cent, respectively. Mining and bulk industrial purposes, and power generation use 6 per cent and 2 per cent, respectively.

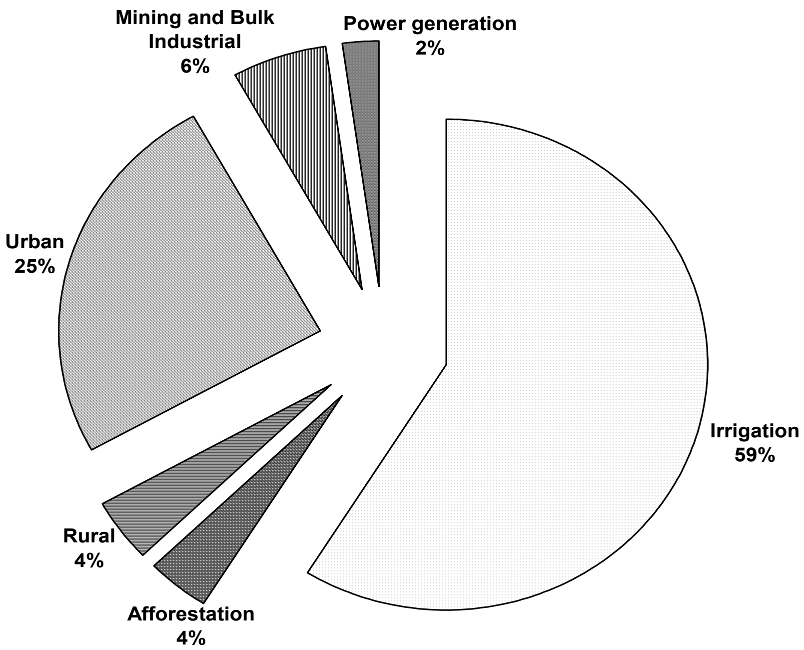

Figure 2 Water requirements by sector in South Africa: 2000.

Source: DWAF (2002)

Nevertheless, water resources are essential to transform society, with the goal of greater social and environmental justice and poverty eradication (Schreiner and van Koppen 2002). Rural people require water for drinking, washing, cooking and for productive purposes such as farming, livestock, forestry, fisheries and small-scale industries that deal with income poverty. Almost 50 per cent of the population is 'income-poor', spending less than R353 per adult equivalent per month. About 70 per cent of these poor people live in rural areas (Schreiner and van Koppen 2002).

Table 1 highlights a number of selected socio-economic indicators in South Africa in 2001. About 23 per cent and 32 per cent of the rural population depend on remittances and pensions, and grants, respectively. In addition, only approximately 24 per cent of rural people have access to piped water on site and only 15 per cent have access to sanitation. The additional charge on water used by economic sectors might lead to both a more effective allocation and a lower use of water resources, and possibly a positive impact on poverty alleviation. This would translate into more water being available for drinking, washing and productive activities, which might increase the income of the poor and reduce the number of people affected by poverty. However, this study only addresses poverty reduction options and not necessarily inequality.

Table 1 Selected socio-economic indicators: 2001.

	National	Rural
Unemployment rate (%):		
- Official (restricted) definition	26.4	33.9
- Unofficial (expanded) definition	37.0	52.2
Portion of household (%):		
- With piped water in the dwelling or on site	65.7	24.3
- Using mainly wood for cooking	19.6	53.8
- Using mainly electricity for cooking	52.5	18.3
- Using mainly paraffin for cooking	21.1	19.2
- With access to hygienic sanitation	62.2	18.0
- Where refuse / rubbish is removed by a local authority	54.8	15.5
- With access to telephone	33.7	22.3
- Within 14 minutes of nearest clinic	36.3	20.8
- Within 14 minutes of nearest primary school	54.3	41.7
- Within 14 minutes of nearest food market	50.9	40.1
- Dependent on remittances	13.8	23.5
- Dependent on pensions and grants	17.8	32.2
- With a radio	79.1	72.2
- With a TV	56.4	35.0

Source: Statistics South Africa (2002).

The above discussion demonstrates the scarcity of water in South Africa, as well as the prevalence of poverty. The next question regards how water resources are managed. To that effect, a consensus was reached at the Dublin Conference on Water and the Environment that water should be regarded as an economic good (Briscoe 1996, Savenije and van der Zaag 2001, Perry *et al.* 1997). There are two schools of thought on the interpretation of water having an economic value (Savenije and van der Zaag 2001, Perry *et al.* 1997). The first school maintains that water should be priced at its economic value (as with other private goods, subject to allocation through competitive market pricing). In other words, water should be allocated to its best uses. The second school maintains that water as an economic good should be exempt from competitive market pricing and treated as a basic human need, which does not necessarily involve financial transactions. This paper adopts the position that water should be priced at its economic value, while still ensuring that poor people have access to water resources. The value of water can be defined as 'the maximum amount water users are willing to pay for the use of this resource, such that marginal cost and marginal benefit are equal' (Briscoe 1996 and Perry *et al*, 2001).

In South Africa, according to the National Water Act (Act No 36 of 1998), the Government is regarded as the public trustee of the nation's water resources and "must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons" (MacKay 2003). Under previous legislation in South Africa, the pricing of water did not generally take into account i) the real cost of managing water, ii) the cost of water supply and iii) the scarcity value of water (MacKay 2003:64). The capital costs of government water schemes supplying mainly agricultural water users (and some urban bulk water suppliers and industrial users) were financed by the Government. In addition, operation and maintenance costs were often not fully recovered from these water users (MacKay 2003:64-65).

The principle behind current water pricing policies in South Africa is that payment for water should be at a level that reflects its scarcity, except for water required to meet basic human needs. Currently 25 litres of water per day per person is assumed to meet these needs. The current pricing policy is structured into three tiers (CSIR 2001):

- First tier: raw water tariffs administered by DWAF for the sale of water to the Water Boards;
- Second tier: Water Boards set the wholesale price of water to bulk water users like municipalities and industries (such as Eskom, Sasol);
- Third tier: municipalities determine the price of water for end-users like households and industries.

A rise in raw water tariffs will automatically lead to an increase in price within the second and third tiers. According to the Water Act, all water users should be registered and pay for water. Water use is classified into three kinds: 1) *schedule 1 authorisation*, which grants lawful access for reasonable domestic use, small gardening and livestock watering without paying water tariffs or charges; 2) *general authorisation,* under which water use is authorised for a group of water users, as long as certain minimum requirements are met; and 3) *water use licence,* under which individual water users apply to DWAF for a licence to use water. In this case, water should preferably be allocated to those users generating the highest social, economic or environmental value and promote equity.

Water pricing can be based on a number of strategies that include full supply cost, full economic cost and full cost of water (Figure 3). The South African Government is introducing a water resource management charge to recover some of the costs for water management and to reflect water scarcity in the country. This means that the Government is moving towards the 'full economic costs of water' pricing strategy by taking into account the supply cost and opportunity cost of water.

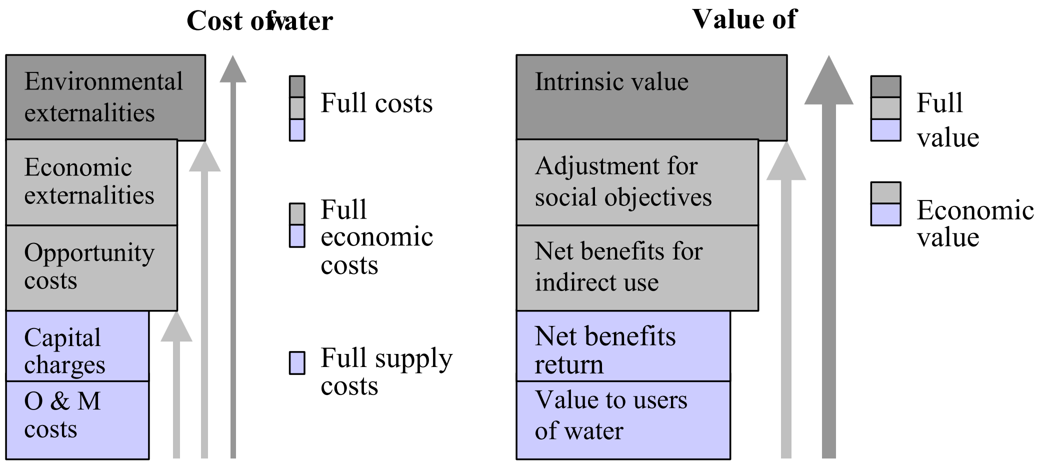

Figure 3: Underlying principles for the cost and value of water.

Source: King (2004), adapted from Rogers, de Silva and Bhatia (2001).

3. Double dividend

According to the double dividend theory, the revenues of environmental taxes can be used to lower other (distortionary) taxes, and therefore lower the (economic) cost of the environmental tax. The positive effects of lowering other taxes could even outweigh the negative effects of a rise in environmental taxes. This produces a so-called 'double dividend': both the environment (first dividend) and the economy (second dividend) will be in better shape than before the environmental tax reform. This would, of course, be welcomed by policy-makers who want to use environmental taxes to curb pollution, but find it hard to sell a drop in GDP or employment. It also explains why the double dividend theory has become a popular research theme.

In the early phases of the double dividend theory bold statements were made about the general validity or invalidity of the theory. These statements were based either on partial models of the economy or simple one-factor GE models that assumed competitive markets (see e.g. Pearce (1991) and Bovenberg and De Mooij (1994)). Subsequent analysis focused on multiple production factor models and allowed for a distorted labour market. This analysis led to more nuanced statements about the possibility of a double dividend and will be discussed in the next two sections.

3.1 Multiple production factors

Proponents of the one-factor models claim it is impossible to attain a double dividend because the environmental tax would be more distortionary (in a purely economic sense) than the factor tax it tries to address (Bovenberg and de Mooij, 1994; Goulder et al., 1997). Adding another production factor (usually capital; one-factor models typically use just labour) to the modelled economy introduces the possibility of inefficiencies in the tax system. From a tax-efficiency point of view, taxes on the two production factors should have the same marginal efficiency costs or marginal excess burden (MEB), that is, the loss of overall production efficiency due to taxation[4]. If the MEBs are not equal, reducing this difference diminishes the distortions in the economy caused by taxation.

In the double dividend literature this inefficiency is "used" to create possible economic gains from the introduction of an environmental tax. This happens if the environmental tax shifts the tax burden from the over-taxed factor (with the higher MEB) to the under-taxed factor (with the lower MEB). As stated by Goulder (1994), the gain is larger if (i) the difference in MEBs is larger; (ii) the burden of the environmental tax falls mainly on the under-taxed factor; and (iii) the recycling of revenues mainly reduces the burden of the over-taxed factor.

Substitution elasticities between labour, capital and energy (the polluting input) are also important. When fixed, capital should be a poor substitute for energy, while labour should be a good substitute for energy. With an elastic capital supply, the reverse is true (De Mooij and Bovenberg, 1998).

This efficiency gain has to be large enough to overcome the negative effects inherent in an environmental tax (its narrowness, and the extra distortionary costs that arise from taxing inputs or goods instead of taxing production factors directly)[5].

The effects of tax shifting have also been studied with empirical GE models. Goulder (1995), Bovenberg and Goulder (1997) and Jorgenson and Wilcoxen (1993) all studied the results of a revenue neutral environmental tax reform for the United States with an intertemporal numerical GE analysis. Goulder (1995), and Bovenberg and Goulder (1997) failed to find a double dividend. In all their scenarios the environmental tax was more distortionary than the taxes it replaces and the economic costs of the tax reform are therefore always positive. The main reason for this is the relative narrowness of the environmental tax. Jorgenson and Wilcoxen (1993) did find a double dividend under certain conditions. Irrespective of the end result, the costs or benefits of the tax reform varied with the scenario chosen, and they changed in line with Goulders' (1994) expectations: the lower the costs, the larger the difference in MEB, and the more the tax burden was shifted from the over-taxed to the under-taxed factor.

3.2 Non-competitive markets: involuntary unemployment

The second main improvement in double dividend analysis was the inclusion of involuntary unemployment. In the literature, involuntary unemployment has been incorporated in the GE analysis in several different ways, but usually some model of wage-bargaining

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4 The MEB of a labour tax depends on its level and on the (compensated) wage elasticity of labour supply: the larger this elasticity, the greater the distortion. For a capital tax in a closed economy it is again the level and the intertemporal elasticity of substitution in consumption: the larger the elasticity, the larger the distortion along the intertemporal dimension (the margin of choice between consuming today and consuming in future).

5 The broader the tax base the lower the distortion. Environmental taxes, however, are relatively narrow by nature and on purpose because they are meant to change specific behaviour (Goulder, 1994). In the theoretical tax literature, taxes on intermediate inputs generally have larger welfare costs than do equal-revenue taxes on primary factors because they distort both the intermediate input choice and factor markets, instead of just distorting factor markets (Goulder, 1995: 288).

between firms and workers is used. Bovenberg and van der Ploeg (1998), for instance, use a search model of the labour market with individual worker-firm bargaining. In another paper, Strand (1998) assumes a monopoly union that unilaterally determines the wage, after which a fixed number of firms determine employment. In Koskela, Schöb and Sinn (1998) a monopolistic firm determines employment, this time after bargaining over wages with a small trade union.

In these papers, the double dividend depends on the effect the green tax reform has on the bargaining positions of firms and workers. For employment (not necessarily welfare) to increase, producer wages have to decrease. This happens if workers' bargaining position deteriorates or that of the firm(s) improve. This is the case if workers' outside option (e.g. income under unemployment or in the informal sector) worsens or if the firm's labour demand becomes more elastic with respect to wages. Another way to reduce wages is to shift the tax burden to the unemployed, as in the paper by Bovenberg and van der Ploeg (1998).

3.3 Distributional effects

Besides raising revenue, the most important function of taxation, is the (re)distribution of income between members of society. This distribution is also the main reason why tax systems deviate from optimality (in the absence of externalities it would be optimal to have a lump sum tax). Unfortunately, the way an environmental tax reform affects distribution has not been studied in much detail in the double dividend literature. The scarce information we do have points to a small negative distributional effect, but this, of course, depends on the specific form of the tax return (see for example Ekins and Barker (2001) and Bach *et al*. (2002))[6].

Shifting the tax burden to the unemployed or those working in the informal sector, (as is done by Bovenberg and van der Ploeg (1998)) in order to increase employment will obviously have negative income effects on the lowest income groups.

In conclusion, a double dividend seems possible but is by no means certain or automatic. Existing taxes and distortions in the labour market, together with the specific form of the tax reform, will determine the ultimate outcome.

4. Model and data

The model used here is similar to the general equilibrium ORANI-G-model of the Australian economy (Harrison and Pearson 1996). It is a static model with an overall Leontief production structure, and CES sub-structures for (i) the choice between labour, capital and land, (ii) the choice between the different labour types in the model, and (iii) the choice between imported and domestic inputs into the production process. Household demand is modelled as a linear expenditure system that differentiates between necessities and luxury goods, while households' choice between imported and domestic goods is modelled using the CES structure.

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6 However, this would again diminish the increased efficiency of the tax system and could, depending on the measures taken, prevent a double dividend.

The model is based on the official 1998 social accounting matrix (SAM) of South Africa, published by StatsSA (SSA 2001). This SAM divides households into 12 income and 4 ethnic groups, and distinguishes 27 sectors. For the purpose of this study, the energy and water intensive sectors are further split into 39 sectors. The elasticities used for the CES functions in the model have been taken from De Wet (2003). The model's closure rules reflect a short-run time horizon. The capital stock is assumed to be fixed, while the rate of return on capital is allowed to change. Labour supply is modelled in the typical ORANI way, by assuming fixed real wages in the short run, implying perfectly elastic labour supply. The supply of land is also assumed to be inelastic.

With reference to macroeconomic variables, it is assumed that aggregate investment, government consumption and inventories are exogenous, while consumption and the trade balance are endogenous. This specification gives us an insight into the effect of the suggested policies on South Africa's consumption and competitiveness. All technological change variables and all tax rates are exogenous to the model. Finally, the nominal exchange rate is set to be the numeraire in each of the simulations.

4.1 Model

The water supply and use accounts of the CSIR (2001) were used to create a vector of "Taxable water" for each industry in the SAM, as well as a vector of "Extra water charges" that may be paid according to volumes of water used. The former is a vector of water volumes which includes all taxable water (namely, water extracted from underground or rivers, or water received from the formal water sector). In addition to the standard model, variables are also defined for taxable water used, and extra water charges, so as to calculate changes in total revenue raised, and changes in water demand.

The core water equation added to the UPGEM model is as follows: 'Revenue raised is equal to the tax rate per volume times the volume of water (X)' or:

$$R = T.X \tag{1}$$

UPGEM operates in percentage or absolute change form, and not in absolute levels. From equation (1) stated above, the change in revenue (dR) is approximately equal to the tax rate (T) times the change in the base (dX) plus the base (X) times the change in the rate (dT):

$$\begin{aligned} dR &= T.dX + X.dT \\ &= T.X.x/100 + X.dT \end{aligned} \tag{2a}$$

$$= R.x/100 + X.dT \tag{2b}$$

This is with x the percentage change in X[7]. Equation (2b) is used in the model to calculate the absolute changes in revenue caused by charges on water consumption for all industries. The changes in the tax rates are exogenous, and shocked according to various scenarios outlined below. All the other variables are entered into, or calculated by, the model. Note that variable x is the percentage change in water consumption by industries,

[7] If x is the percentage change in X, then we know x = 100*dX/X, so that dX = x.X/100.

and it is an endogenous variable, that is, calculated by the model. We expect that an additional charge on water will lead to a decrease in water consumption. Total revenue from the extra water charges are added to total government revenue.

4.2 Water scenarios

As mentioned in Section 2, this study has adopted the 'full economic value of all the water' pricing strategy. The following scenarios were run by the UPGEM model to try and adhere to the suggestions proposed by water authorities and experts:

1. A surcharge of 10c per m^3 water used by forestry, irrigated agriculture & all mining industries;

On the recycling side two simulations were performed:

2. A decrease of 0.0007 in the overall level of direct taxation on capital and labour; and
3. A decrease in the overall level of sales tax on final consumption.

No unambiguous improvement in consumption levels of any race groups in the poorest three household groups was found in any one of the scenarios. We therefore had to refine the scenarios further. Instead of placing a surcharge on all irrigated agriculture, irrigated agriculture was split into 'field crops' and 'horticulture', and the results reported separately. The irrigated agriculture in the SAM was split using input-output tables supplied by Connningarth Consultants Consulting Economists for 1996 for South Africa. Mining was also split into three components – 'gold', 'coal', and 'other mining' – and results are reported separately as well.

4.3 Simulation results

Environmental effects

The first of a 'double' or 'triple dividend' is the environmental dividend reaped. Triple dividend can simply be thought of as: environment dividend plus efficiency dividend (GDP) plus poverty dividend. The welfare change is split up into changes due to environment, profits and employment. Table 2 below illustrates that all the simulations do yield the first dividend, whether the revenue collected is recycled through a direct or indirect tax break. The first dividend here is a net decrease in the amount of water consumed per unit of real government revenue. An additional charge on water consumption always leads to a decrease in water demand. All that is needed for the environmental dividend to occur is that the increase in water consumption that results from a direct or indirect tax break is less than the decrease due to the water charge. The model results as shown in Table 2 indicate that this is expected to be the case.

The water charge increases the price of water and directly affects the amount of water consumed. The model predicts that the water charge will lead to a decline in water consumption in the forestry and irrigated agriculture sectors by 32 per cent and 6 per cent respectively. Water consumption by the mining sector will decrease by only 3 per cent. The decrease in water consumption as a result of the water charge is greater than the increase in water consumption because of tax breaks, thereby yielding the environmental dividend. However, a tax break affects all commodities, not only water. Consumers will use the extra income to demand more of all commodities, including water. However, water is a necessity, and the demand for it will increase very little, as the results in table show.

Table 2 Effects of various charges on percentage change in water consumption (per unit of government revenue).

	Recycling of revenue	Direct tax break	Indirect tax break
Water charge	Change in water use	0.0007	0.0009
Charge on Forestry	0.316	✔	✔
Charge on Mining	0.026	✔	✔
Gold	0.028	✔	✔
Coal	0.026	✔	✔
Other	0.025	✔	✔
Charge on irrigated agriculture	0.055	✔	✔
Field crops	0.066	✔	✔
Horticulture	0.033	✔	✔

Source: model results.

Economic effects

The second dividend is the effect on the total economy, and is determined using the concept of marginal excess burden. The marginal excess burden (MEB) was defined above as ‘the loss of overall production efficiency due to taxation’ and is defined here in model terms as:

MEB = change in real GDP divided by the change in real government revenue

The MEB’s for all eight water charge policy measures, as well as the two recycling measures, are given (and compared) in Table 3. A double dividend is indicated by a ✔ in the table. This occurs when the increase in real GDP per unit of real government revenue lost as a result of a tax break (recycling policy) is larger than the decrease in real GDP per unit of real government revenue collected from a new water charge.

A charge on water consumed by the mining industry is expected to lead to a decrease in real GDP by 54.8 cents per Rand of real government revenue collected from the tax, while recycling via either a direct or indirect tax break led to a GDP increase by 59.1 and 72.5 cents per Rand of real government revenue forsaken by the Government respectively. This suggests that a net gain to the economy can be expected. However, if only gold mining is charged, it will not render a double dividend, and neither if only applied to coal mining, if the direct tax break is the method of recycling. Other mining industries offer quite a different result in that GDP only decreases by 25 cents per Rand with the extra water charge. An additional charge on water consumption by irrigated agriculture renders double dividends, whether the tax is levied on field crops only, or horticultural crops only, or on both. The damage done in terms of MEB is smaller with field crops than horticulture. However, additional water consumed by forestry does not yield a double dividend.

The percentage change in total employment per unit of real government revenue collected was also calculated, and the ticks and crosses follow exactly the same pattern as in Table 3 above. That is, employment and GDP per unit of real government revenue are closely related to each other. The explanation is simply that the total production function in the model has Leontief and CES characteristics, in terms of intermediate and primary inputs, so that GDP and employment will always move in the same direction as a result of an exogenous shock.

Table 3 Effects of various taxes on change in real GDP (per unit of government revenue (MEB)).

	Recycling of revenue	Direct tax break	Indirect tax break
Water use charge	MEB/Employment	0.591	0.725
Charge on Forestry	0.828	✕	✕
Charge on Mining	0.548	✔	✔
Gold	0.965	✕	✕
Coal	0.659	✕	✔
Other mining	0.249	✔	✔
Charge irrigated agriculture	0.374	✔	✔
Field crops	0.340	✔	✔
Horticulture	0.444	✔	✔

Poverty effects

The criterion used to measure an improvement in poverty levels is the percentage change in total real consumption of the three poorest household groups in the economy, by race. The model has eleven household groups and four race groups and it calculated consumption for each group by commodity, as well as total consumption. The results of total consumption for the poorest household group is given in Table 4. This table is, in fact, representative of all the three poorest groups as the results for all these groups are similar.

It is clear from Table 4 that some policy combinations deliver a net improvement for one race group while having a detrimental effect on another. The only water charge that could be recycled in a way that would benefit all four race groups within the poorest groups of households, is a tax on water consumption by mining industries other than gold and coal. The table shows why the initial three scenarios proposed by policy-makers (scenarios 1, 2 and 3 in the Table, as discussed in Section 4.2) are not sufficient to solve the water problem in South Africa: each one of them would harm at least one of the poorest household categories. Therefore scenarios 2a, 2b, 2c, 3a and 3b were added. For example, if all mining industries' water consumption is taxed, poor Africans would be worse off. The model reveals that a better policy would be to only tax water consumption by "other" mining industries excluding coal and gold.

With regard to irrigated agriculture, it makes sense to differentiate between water charges for field crops and for horticultural crops separately. The model shows that a tax on irrigated horticultural crops has a more severe influence on the consumption of the poorest groups, in that at least one group is made worse off through this tax .On the other hand, with irrigated field crops, at most one group is made worse off.

Table 4 Effects of various taxes on percentage change in real consumption per unit of government revenue – poorest group (H01).

% change in real household consumption per R1b change in real government income	Recycling of revenue	Direct tax break	Indirect tax break
Water charge	Cons/R	0.122 a	0.150 a
	Poorest households	0.115 c	0.139 c
		0.142 i	0.168 i
		0.128 w	0.152 w
1. Charge on forestry	0.403 a	✗	✗
	0.243 c	✗	✗
	0.111 i	✓	✓
	0.268 w	✗	✗
2. Charge on mining	0.234 a	✗	✗
	0.036 c	✓	✓
	0.025 i	✓	✓
	0.092 w	✓	✓
2a. Gold	0.439a	✗	✗
	0.025c	✓	✓
	0.021i	✓	✓
	0.074w	✓	✓
2b. Coal	0.211a	✗	✗
	0.041c	✓	✓
	0.076i	✓	✓
	0.198w	✗	✗
2c. Other mining	0.079a	✓	✓
	0.037c	✓	✓
	0.015i	✓	✓
	0.056w	✓	✓
3. Charge on irrigated agriculture	0.111 a	✓	✓
	0.146 c	✗	✗
	0.032 i	✓	✓
	0.051 w	✓	✓
3a. Field crops	0.122a	0	✓
	0.162c	✗	✗
	0.071i	✓	✓
	0.073w	✓	✓
3b. Horticulture	0.148a	✗	0
	0.210c	✗	✗
	0.032i	✓	✓
	0.059w	✓	✓

Note: Race groups: a – African; c – Coloureds; i – Indians and w – Whites .

5. Discussion of results

Extra water charges on forestry are detrimental to three of the four race groups in the poorest household group, including Africans who comprise close to 90 per cent of this group. The eight key commodities that Africans spend most of their income on are – in order of importance - food, petroleum, real estate, textiles, electricity, transport services, and other manufacturing and agricultural goods.

The direct impact of extra water charges on forestry is, firstly, an increase in the cost of the forestry industry and hence its prices, and secondly on wood, paper and pulp, which is part of other manufacturing. The agricultural sector is the largest intermediate supplier to the food industry, and food is the most important commodity for all households – rich and poor. 'Other manufacturing' is also high on poor consumers' priority list, and these two channels turn out to be significant in having a detrimental effect on the poor.

Extra water charges for mining do not have a direct effect on households in the same way that water charges for forestry and irrigated agriculture do. Households do buy some coal, but no gold or other mining goods, so that there are no direct effects on households from the latter two industries. They influence consumers through the downstream effects on industries who buy the outputs of the mining industries.

The effect from the mining industry as a whole comes mostly from more expensive coal, through two obvious channels. African households consume coal directly, and they consume electricity, of which coal is the most important intermediate input. The gold mining industry has indirect effects only: it sells gold to 'other manufacturing', which is a key commodity for households. Three of its most important suppliers of intermediate goods are petroleum, electricity and 'other manufacturing' – all three key commodities for the poor.

The results that appear in Table 4 also take the recycling of revenues into consideration, and the effects described above should be compared to the increases in consumption of various commodities due to recycling. In general, the recycling benefits all industries, while the environmental taxes harm a few industries severely, and affect others marginally. The recycling of revenues allows consumers to have more of all commodities, and hence also more of the key commodities which they consume the most. The default net outcome of the combined policy options – water charges and recycling – should therefore be beneficial to the consumers, unless the environmental effects are focused on a few key commodities, and outweigh the recycling effects. The extra water charges on 'other mining' are a case in point. There are few negative effects on consumers since they do not buy 'other mining' commodities. The most important indirect effects are on petroleum, basic iron and steel, and construction, of which only the first is important for consumers. Hence the results demonstrate positive net effects on consumption by the poor.

Extra water charges on irrigated agriculture directly increase the cost of field and horticultural production. Field and horticultural products comprise a large proportion of agricultural commodities, and an increase in their prices directly affects the prices of industries buying them as intermediate inputs. The greatest demand for agricultural goods comes from food, 'other manufacturing', petroleum and textiles, all important to poor households. However, recycling via either a direct or indirect tax break outweighs the negative effects of the tax on irrigated agriculture.

Two features of the effect of the water charge on irrigated agriculture (recycled) are difficult to explain: (i) the only group that is not made better off is the Coloureds, and (ii) a water charge on horticulture seems to have more negative effects than a water charge on field crops. Coloureds consume roughly the same key commodities as Africans, but the order of importance of commodities differs. For Coloureds, real estate and electricity have higher priority in their consumption preferences. Both of these have high intermediate inputs of petroleum in their production processes, and petroleum is affected negatively by an increase in agricultural prices.

The good news is that with a water charge policy that involves irrigated field crops, Africans are made better off, whichever way of recycling used. They comprise more than 89 per cent of total consumption in their six most important commodities, and a very high proportion of all commodities consumed by the poorest groups. The Coloured population group consumes less than 10 per cent of all commodities in the poorest group and is the only group to be harmed by a tax on irrigated field crops.

It is interesting to compare the above results with those for the richest group of households, presented in Table 5. A charge on water consumed by 'other mining' industries still improves real consumption levels, as with the poorest groups. Moreover, a general tax on all irrigated agriculture also benefits this richest group, whether the revenue is recycled through a direct or indirect tax break. However, if a water charge is applied to field and horticultural crops separately, it becomes apparent that the benefits accruing to the rich group would come from the field crops. If a water charge is only applied to horticulture, two race groups within the rich group will become worse off.

All the simulation results are summarised in Table 6. The first tick in each cell shows the first dividend: the environmental effects are positive in all cases. The second tick or cross shows whether a double dividend has been achieved with the combination of policies, while the third tick or cross shows a triple dividend. Notice that the last crosses vary in size: the larger the cross, the more race groups within the poorest household group are harmed by the specific policy option. For example, a small cross in the third column implies that the policy option is fairly good, but not perfect. There are a number of policy combinations that render double dividends, but we are interested in poverty reduction with environmental management, and this triple dividend is only obtained when a tax on 'other mining' is combined with either one of the recycling methods. However, recycling the revenues of extra water charges on irrigated field crops benefits more than 90 per cent of all poor households, and should also be taken into consideration as a viable policy option.

Table 5 Effects of various taxes on percentage change in real consumption per unit of government revenue – richest group (H12).

% change in real household consumption per R1b change in real government income		0 Recycling of revenue	5 Direct tax break	6 Indirect tax break
0	Water charge	Cons/R	0.134 a	0.175 a
		H12	0.142 c	0.183 c
			0.163 i	0.204 i
			0.126 w	0.158 w
1	Charge on forestry	0.403 a	✗	✗
		0.243 c	✗	✗
		0.111 i	✓	✓
		0.268 w	✗	✗
2	Charge on mining	0.234 a	✗	✗
		0.036 c	✓	✓
		0.025 i	✓	✓
		0.092 w	✓	✓
2a	Gold	0.467a	✗	✗
		0.027c	✓	✓
		0.026i	✓	✓
		0.134w	✗	✓
2b	Coal	0.192a	✗	✗
		0.038c	✓	✓
		0.077i	✓	✓
		0.157w	✗	✓
2c	Other	0.078a	✓	✓
		0.041c	✓	✓
		0.019i	✓	✓
		0.055w	✓	✓
3	Charge on irrigated agriculture	0.111 a	✓	✓
		0.146 c	✗	✓
		0.032 i	✓	✓
		0.051 w	✓	✓
3a	Field	0.081a	✓	✓
		0.123c	✓	✓
		0.035i	✓	✓
		0.034w	✓	✓
3b	Horticulture	0.175a	✗	✗
		0.193c	✗	✗
		0.025i	✓	✓
		0.086w	✓	✓

Note: Race groups: a – African; c – Coloureds; i – Indians and w – Whites.

Table 6 Summary of results: Water; MEB (employment); Consumption.

Water charge	Direct tax break	Indirect tax break
Charge on Forestry	✓✗✗	✓✗✗
Charge on Mining	✓✓✗	✓✓✗
Gold mining	✓✗✗	✓✗✗
Coal mining	✓✗✗	✓✓✗
Other mining	✓✓✓	✓✓✓
Charge irrigated agriculture	✓✓✗	✓✓✗
Field crops	✓✓✗	✓✓✗
Horticultural crops	✓✓✗	✓✓✗

6. Conclusions

The simulation results presented in this paper are satisfactory. The largest water user is irrigated agriculture, and crucially, a tax on water used by this sector would render the desired 'triple dividends' for all four-race groups. It also renders double dividends for all race groups except poor Coloured people who would be made worse off by this policy. However, this group constitutes a small portion of all consumption – less than 10 per cent.

A triple dividend was derived by introducing a water charge on water consumption in the mining sector (other than gold and coal). In conclusion, it seems that an additional water charge on irrigated field crops in conjunction with a water charge on some aspects of the mining sector stand the highest chance of yielding dividends in terms of less water used, least impacts on poverty reduction amongst the poor and least impacts on the economy. A more detailed analysis with more specific charges needs to be carried out to further substantiate this preliminary conclusion.

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